Bio-Synthesis of ZnSe and CdSe Conventional and Inverted Core Shell Nanostructure

''बेटी बचाओ, बेटी पढ़ाओ''

A Synopsis

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INTRODUCTION: -

A Nanostructure can be defined as, any material having 1-D in nano range i.e., 1-100nm. The transition to the nano regime occurs whenever the materials dimensions become smaller than the characteristic length scale defining physical properties. The objects in the nano-regime are larger than atoms or molecules but smaller than the structure typically produced for micro technologies. At these sizes, nano systems exhibit interesting behaviour governed by quantum phenomena. The uniqueness of the structural characteristics, energetic response, dynamics, physics and chemistry of nanosystems is indeed novel and constitutes the experimental and conceptual background for novel devices. Fig.1 schematically represents the various forms and corresponding applications of Nanomaterials. Preparation of nanomaterial structure can be done by method of Lithography. A quantum dot is 0-D and has limited number of atoms, display discrete energy states.

Two major factors can influence unique properties of QD's:

1. **Quantum confinement: -** When size of semiconductor decreases then energy gap increases, due to which electron-hole (exciton) confined in a discrete energy level.
2. **Surface Energy: -** Surface-to-volume ratio increases with decrease in size.

Recent developments in nanoscience and technology and the demonstration of quantum size effects in nanostructures, implies that the most of the novel devices will be based on properties of nanomaterials.

The inorganic NP such as Silver, Copper, Gold, Zinc, CuO, ZnO have profound antibacterial activities.

Among inorganic NPs, ZnO, NPs are of particular interest because they can be prepared easily inexpensive and safe material for human beings and animals.

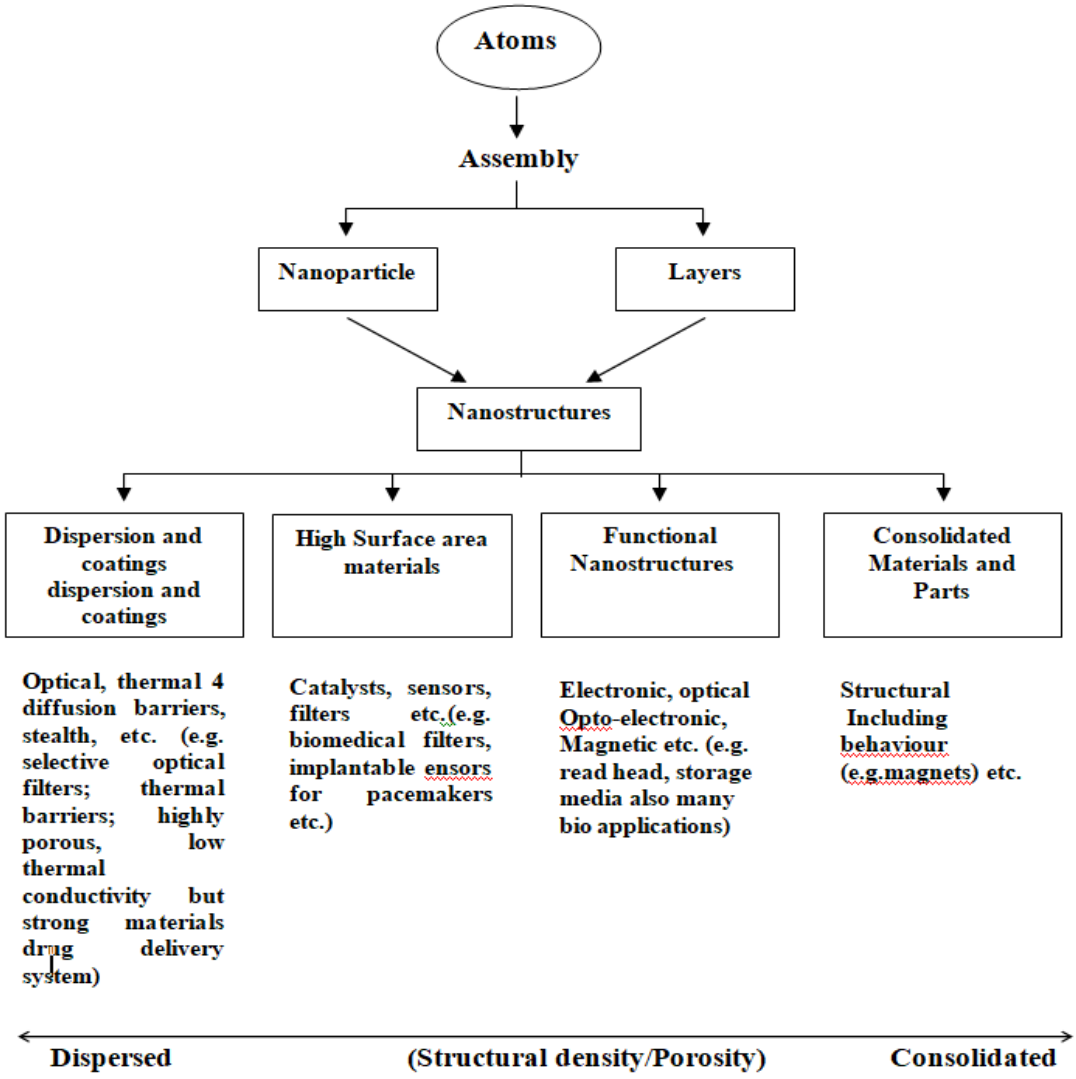
Atoms
Assembly
Nanoparticle
Layers
Nanostructures
Dispersion and coatings dispersion and coatings
High Surface area materials
Functional Nanostructures
Consolidated Materials and Parts
Optical, thermal 4 diffusion barriers, stealth, etc. (e.g. selective optical filters; thermal barriers; highly porous, low thermal conductivity but strong materials drug delivery system)
Catalysts, sensors, filters etc.(e.g. biomedical filters, implantable ensors for pacemakers etc.)
Electronic, optical Opto-electronic, Magnetic etc. (e.g. read head, storage media also many bio applications)
Structural Including behaviour (e.g.magnets) etc.
Dispersed
(Structural density/Porosity)
Consolidated

Figure 1:- Schematic of the nano structure science and technology

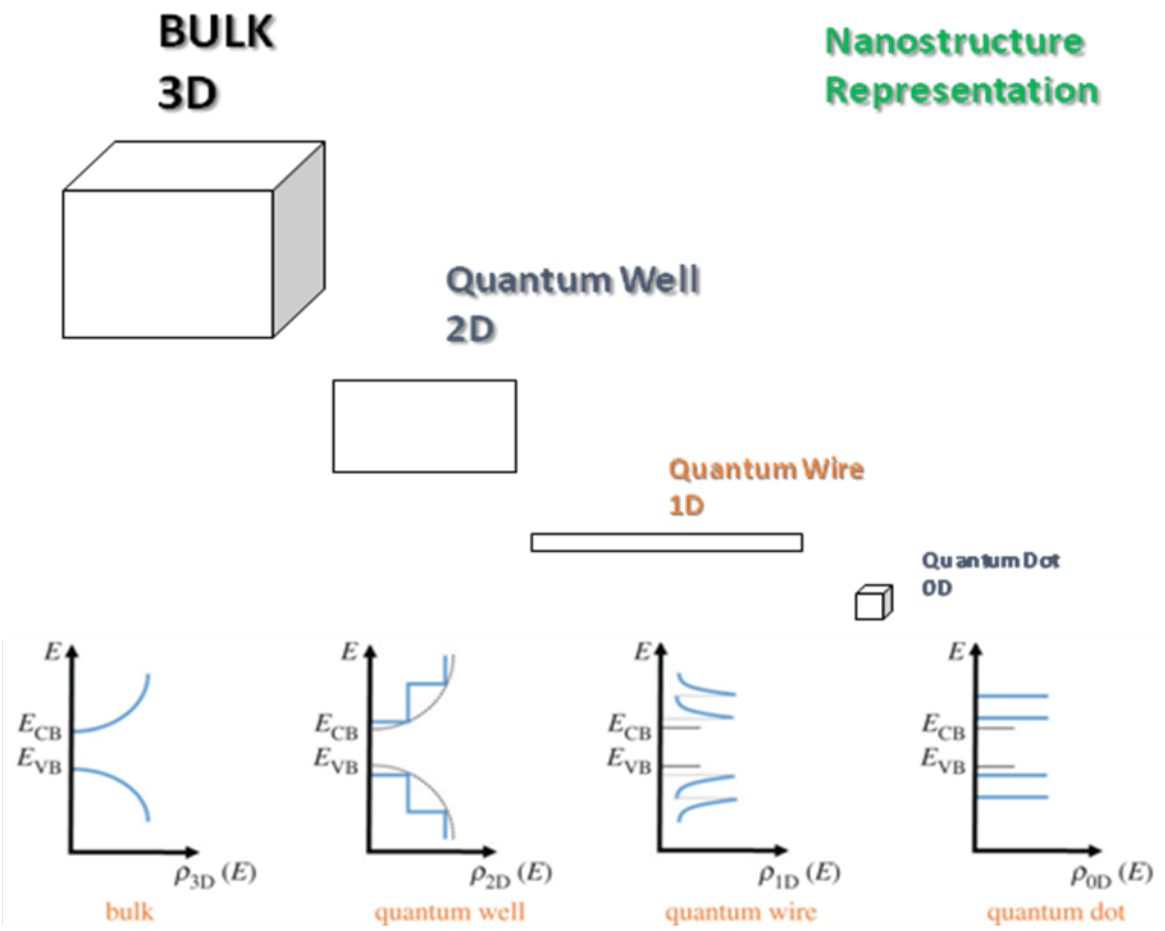

Figure.2: - Schematic of the nano structure.

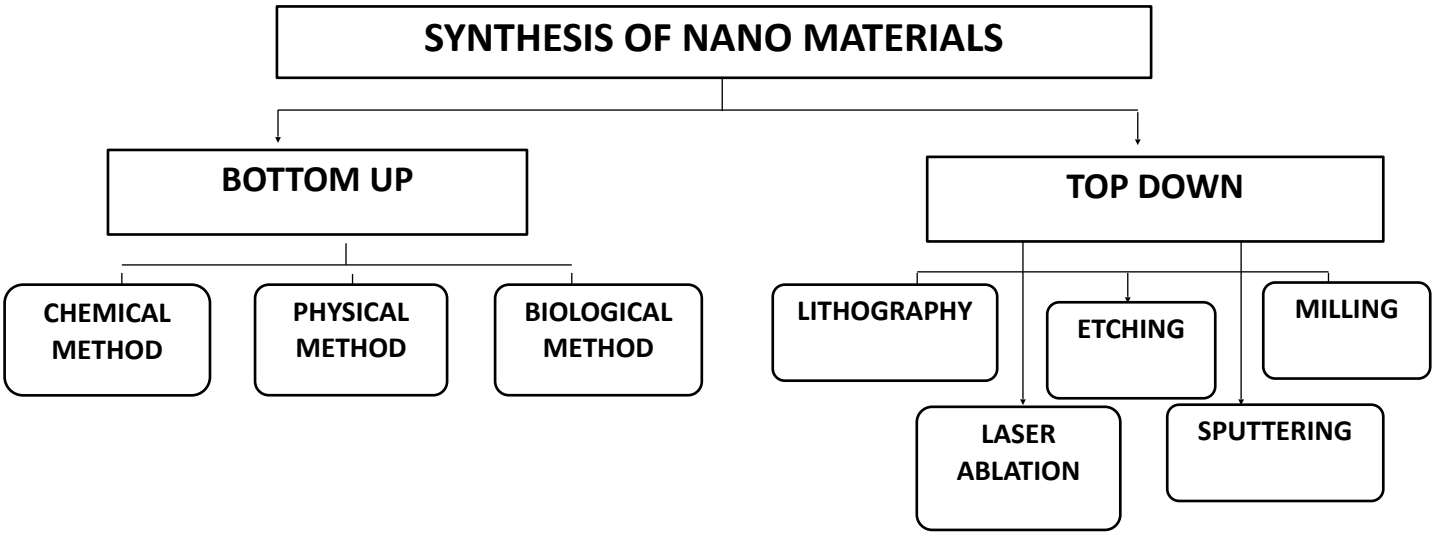

Figure.3: - Synthesis of the nanomaterials.

Recently the trend of preparing Metal/MO NPs using extract of various plants gained popularity.

Core-Shell semiconductors are the particle having a semiconductor core material and a shell of a different semiconducting material.

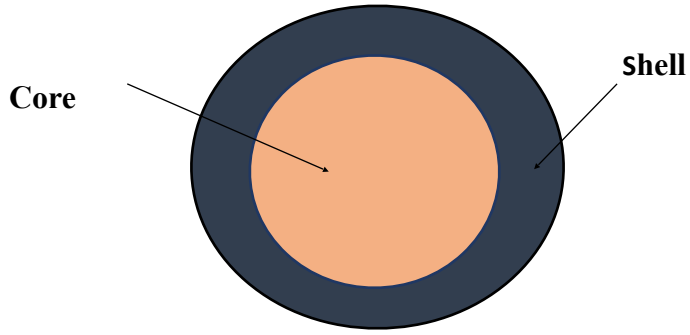

Figure.4: - Schematic of the core shell structure of nanomaterials.

Estimation of the band gap using Vegard's law for determination of alloyed structure revealed a non-linear relationship between the band gap energy and S concentration.

Based on energy band gap, Core/Shell semiconductors are categorized into three parts: -

Type-I (Shell material has wider band gap than Core materials)

Reverse Type-I (band gap of Core materials is larger than Shell materials)

Type-II (either valence or conduction band edge of Shell material lies within the bandgap of the Core materials).

Core Shell QDs are synthesized by two-step process- first the synthesis of core QDs and second subsequent shell growth process. A very wide range of biological resources like microorganisms (algae, fungi, bacteria, viruses) and plants can be used for nanoparticle synthesis.

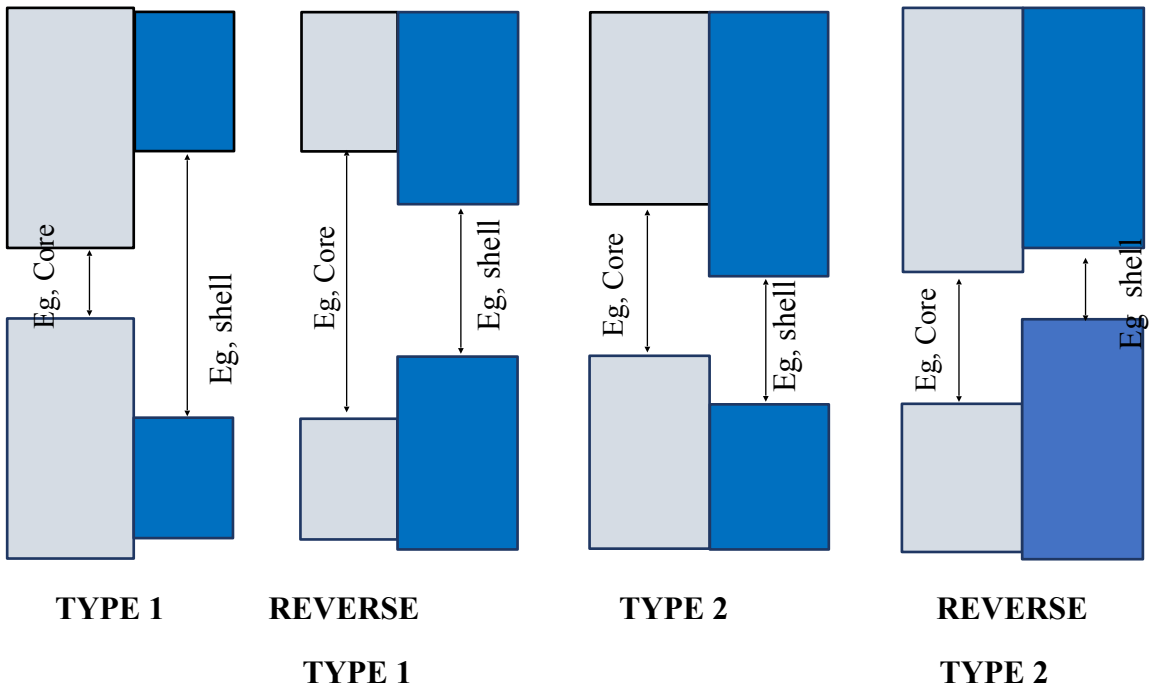

Figure.5: - Based on energy band gap, Core/Shell semiconductors

Synthesis of Core Shell QDs can be done by –

1.Injection Method: - Synthesis of II-VI semiconductor QDs using 'green' hot injection synthesis method. Hot injection method is described by a fast injection of precursors into a hot solution containing another precursor followed by an instant homogenous reaction.

2.Non-Injection Method: - In this method, the single source precursor (e.g., $Li_4[Cd_{10}Se_4(SPh)_{16}]$ for CdSe) was added in dodecyl amine or hexadecyl amine at 80°C under N_2. After dissolving the cluster, the reaction mixture was heated up to 220°C for the growth of QDs. ZnSe and CdSe are prepared via this method.

The performance of semiconductor (ZnSe, CdSe, ZnSe/CdSe, and CdSe /ZnSe) core-shell structures was characterized by-

1. **XRD** (X-ray diffraction) Analysis: - XRD is a technique used to determine the crystallographic structure of a material.
2. **SEM** (Scanning electron microscopy): - SEM provides good resolution of a variety of samples, typically 5 to 10 nm or magnification 10 to 100000 X.
3. **TEM** (Transmission electron microscopy): - It is a technique that uses an electron beam to image a nanoparticle sample, providing a much higher resolution than is possible with light-based imaging techniques.
4. **PL** (Photoluminescence) spectroscopy: - PL (Photoluminescence spectroscopy) uses a laser beam to capture light generated from a substance as it falls from the excited state of the ground state when irradiated by a laser beam.
5. **UV** Spectroscopy: - It is an analytical technique that measures the number of discrete wavelengths of UV or visible light that are absorbed by transmitted through a sample in comparison to a reference or blank sample.
6. **Raman** Spectroscopy: - It is a spectroscopic technique that describes the vibrational modes of molecules. It is used to provide a structural fingerprint to identify molecules.

Nanocrystals synthesized by a chemical route allow us to control their sizes and distribution. These routes include single molecule precursor, sonochemistry, solvothermal synthesis, microwave irradiation, organometallic precursor route, and green chemical applications.

Experimental Analysis

1. **Synthesis of ZnSe/CdSe: -** Cadmium Nitrate [Cd(NO3)2.4H2O] with Sodium Selenite (Na2SeO3) and Zinc nitrate [Zn(NO3)2.6H2O] with Sodium Selenite were used for the synthesis of CdSe and ZnSe respectively. During the synthesis of CdSe, the molar ratio of [Cd (NO3)2.4H2O] to (Na2SeO3) was kept 2:1. Cadmium Nitrate [Cd (NO3)2.4H2O] (0.01 mol) was dissolved in 10mL of milli-Q water and then NH3.H2O was slowly added into the solution, which initially led to the formation of a white precipitate, however, with further addition of ammonia, a clear solution was formed. The synthesis of ZnSe was prepared by taking 2.9747g of Zinc nitrate (0.01 mol) dissolved in 20mL of direct milli-Q water and 0.86g of sodium selenite (Na2SeO3) was dissolved in 15mL of hydrazine hydrate (N2H4.H2O). The obtained dark red CdSe/ZnSe precipitate was separated by centrifuge and its impurities were removed by repeated washing with water, ethanol, and methanol. The synthesized nanocomposite was needed at 120°C.

2. **Characterization Techniques: -** Powder X-ray diffraction (PXRD) pattern was recorded on model Rich Seifer rotation anode X-ray diffractometer with Ni-filtered CuK radiation (λ=1.5406 Å). Transmission electron microscopy (TEM) images, high-resolution transmission electron microscopy (HRTEM) images, and selected-area electron diffraction (SAED) patterns were taken at 200 kV with JEOL-JEM 2010 electron microscope. Scanning electron microscopy (SEM) images were taken with a Hitachi-S 4700 microscope with an accelerating voltage of 15 kV. UV-Vis absorption spectra and photoluminescence (PL) spectra were recorded by using a Varian Cary 5E spectrophotometer and jobinyvon Flurolong-3-11 spectrofluorometer respectively. In the

PL study, a 450W Xe non-lamp was used as the excitation source and a photomultiplier tube with a resolution of 0.2 nm acted as the detector.

OBJECTIVES: -

1. The uses of core shell np's in biological applications.
2. Core shell nano heterostructures applications such as controlled drug delivery and release, bioimaging, diagnosing and many more.
3. To Characterize the Biologically synthesized ZnSe/CdSe nanostructures.
4. The biological imaging using ZnSe/ CdSe conventional & inverted core shell quantum dots.

REVIEW OF LITERATURE: -

1. **Hangbo Li, Rosaria Brescia, Roman Krahne, Giovanni Bertoni Marcelo J.P. Alcocer, Cosimo D'Andrea Francesco scotognella, Francesco Tassone, Macro zanella, Milena De Giorgi and Liberato Manna (2012) "Blue-UV-Emitting ZeSe (Dots/ZnS) Core/Shell Nanocrystals by Sequential cation exchange"** define the

synthesis of ZnSe/ZnS NRs based on sequential cation exchange reactions, starting from CdSe/CdS NRs. These ZnSe/ZnS NRs preserve the morphological and structural features of their parent CdSe/CdS NRs. Direct synthesis of anisotropic nanostructures based on ZnSe and ZnS is not straightforward, rod-shaped ZnSe/ZnS nanocrystals obtained by cation exchange offer a solution in this direction.

2. **Peter Reiss, Myriam Protiere, and Liang Li (2009) "Core/Shell semiconductors Nanocrystals",** define significant progress that was achieved in the field of anisotropic shell growth on spherical CdSe NCs, leading to new rod-shaped CS nanostructures, which combine unique optical properties with appealing self-assembly properties. The developed synthesis method using small-core NCs as seeds in the so-called seeded growth approach opens up the way for a generation of new heterostructures, including nanorods and branched structures such as bi-, tri-, tetra-, or multipods.

3. **Rajib Ghosh Chaudhuri & Shantanu Paria (2011) "Core/Shell Nanoparticles: classes, properties, synthesis Mechanisms, characterization, and applications",** defines the future generation of core/shell nanoparticles will exhibit many new properties that will surely result in new applications with improved performance. The results of this study are for biomedical applications, it describes how magnetic core/ shell nanoparticles show that the magnetic core of metal and MO are usually coated with a biocompatible organic shell.

4. **Hyungarak Kim, Marc Achermann, Laurent P. Balet, Jennifer A. Hollingsworth & Victor I. Klimov (2004) "Synthesis and characterization of Co/cdSe Core/shell Nanocomposites: Bifunctional Magnetic-optical Nanocrystals",** gives a novel

synthetic method for the preparation of all inorganic NCs. That method combines the properties of semiconductor quantum dots and magnetic nanoparticles in core/shell arrangements. Studies are underway to improve QYs by overcoating the core/shell particles with a 2nd wider bandgap shell, such as ZnS, and to grow a spacer layer between the magnetic core and semiconductor to minimize potential quenching of the shell by the metal core

5. **Xin Tong, Zhiming M. Wang (2020) "Core/Shell Quantum Dots, Synthesis, Preperties and Devices",** this book mostly emphasizes how the chemical synthesis and its challenges with a broad prospective have been developed in recent decades for II-VI semiconductor core/shell QDs. The chemical based synthesis and its ability to precisely control shell thickness make highly luminescent semiconductor core/shell QDs for multiple applications, including in LEDs, solar cell, biomedical and many more.

6. **Jianping Ge, Sheng Xu, Jing Zhuang, Xunwang (2006) "Synthesis of CdSe, ZnSe and Zn x Cd1-x Se Nanocrystals and their Silica Sheathed core/shell structures",** they found that ZnSe, CdSe nanocrystals have been prepared at the artificially designed water oil interface using Na_2Se designed water oil interface using Na_2SeO_3, $Cd(NO_3)_2$ and $Zn(NO_3)_2$ as precursors.

7. **Assaf Aharoni, Taleb Mokari, Inna Popov and Uri Banin (2005) "Synthesis of InAs/CdSe/ZnSe/core/shell1/shell2 Structures with Bright and Stable Near-Infrared Fluorescence",** they synthesis a complex InAs/CdSe/ZnSe core shell, where the intermediate CdSe buffer layer decrease strain between the InAs core and ZnSe outer shell. As compared to previously prepared core/shell structures, this structure

leads to significantly improved fluorescence quantum yield and enables growth of much thicker shells.

8. **F. Farsinia, M. Moalei, M. Dehestani and H. Alehdaghi (2019) "White emmisive alloyed core-shell $CdSe_{1-x}S_x$/ZnSe QDs: Synthesis via a novel approach, investigating optical properties and application for photodegradation of methyl orange (MO)",** they found about the Photocatalytic activity of prepared QDs was investigated choosing methyl orange as pollutant target. After ZnSe shell growth, the photocatalytic activity demonstrate an enhancement compared to the barev core particles.

9. **Irshad Ahmad Mir, Kamla Rawat, H.B. Bohidar(2016) "Cadmium-free aqueous synthesis of ZnSe and ZnSe@ZnS core-shell quantum dots and their differential bioanalytic sensing potential",** their approach is to prepare water soluble fluorescent ZnSe@ZnS core-shell QDs, using thioglycolic acid (TGA) ligand as a stabilizer and thiourea as a sulphur source.

10. **Kedarnath, G.; Dey, Sandip; Jain, Vimal K.; Dey, Gautam K. (2006) "Synthesis and characterization of Metal Selenide (ZnSe, CdSe, HgSe) Nanoparticles",** they characterized Metal Selenides (Zn, Cd, Hg) by XRD, EDAX, SEM, AFM, TEM techniques and found about spherical nature with diameter of 15nm (from TEM) of HgSe.

11. **Hakan Aydin, M.R. Karim, Mesut Balban, Hilmi Unlu (2016) "Colloidal Synthesis and Characterization of Cd:Se Molar Ratio and Temperature",** it was observed that for the synthesis with altering Cd:Se initial precursor ratio at a fixed temperature, the samples with high Cd:Se ratio are able to nucleate and grow faster. It

was explored that the influence of operating temperature becomes dominant on the growth of QDs as the Cd:Se initial precursor ratio decreases.

International Research Status of Research

1. Heat-efficient nanoparticles for treating cancer, Oregon State University, 15 Nov, 2022, Scientists have invented a way to make magnetic nanoparticles that get hotter than any previous nanoparticle, improving their cancer fighting ability.

2. Magnetic nanoparticles in biological vehicles individually characterized for the first time, Helmholtz-zentrum Berlin fur Materialien und Energie, 17 May,2022, magnetic nanostructures can be steered via external magnetic fields inside the body to destroy cancer cells by releasing drugs.

3. Researchers analyzed circulating currents inside gold nanoparticles university of Jyvaskyla, Finland, 30 April, 2021, Researcher have developed a method that allows for simulation and visualization of magnetic-field-induced electron currents inside gold nanoparticles. By this method we can accurately analyse magnetic effects in nuclear magnetic resonance inside nano structures.

4. Liu S, Li J, Gu L, Wu K, Xing H, 7 Nov, 2022, Nanoparticles for Chemoimmunotherapy against Triple-Negative Breast Cancer, in this review, they introduce the immunomodulatory effects of chemotherapy and for treating TNBC combined mechanisms of chemoimmunotherapy, followed by a summary of nanoparticle-mediated chemoimmunotherapeutic strategies used. While considering avenues of investigation to enable advances in the field, this synthesis of relevant findings in the field merits contemplation.

5. Bichiral nanoparticles: A new Structural design for manipulating the spin state of light, 18 Oct, 2022, (www.nanowerk.com) Scientists form the College of Chemistry and Molecular Sciences at Wuhan University reported a novel class of chiral materials called bichiral nanoparticles that can easily tune the sign of circular dichroism (CD) through the hybridization of bichiral centres without inverting the geometric chirality.

6. Gabriel Amani Kaningini, Shohreh Azizi, Keletso Cecilia Mohale, Malik Maaza, Green synthesis and characterization of zinc oxide nanoparticles using bush tea (Athrixia phylicoides DC) natural extract: assessment of the synthesis process, 23 Aug, 2022, describes that Nanoparticles are globally synthesized for their antimicrobial, anti-inflammatory, wound healing, catalytic, magnetic, optical, and electronic properties that have put them at the forefront of a wide variety of studies. Due to technological and medicinal applications, ZnO has received much consideration. In this study, they report on the synthesis process of ZnO nanoparticles using Athrixia phylicoides DC natural extract as a reducing agent.

7. Nancy Willian, Syukri Syukri, Hilfi Pardi, 16 May, 2022, Marine plant mediated green synthesis of silver nanoparticles using mangrove Rhizophora stylosa: Effect of variable process and their antibacterial activity, is about how most natural plants used in the synthesis of silver nanoparticles are limited to marine plants. Colloidal silver nanoparticles (AgNPs) should have appropriate properties such as homogeneous shapes, small and narrow particle size distribution, and long time stability, to carry out its applications. The aim of this study is to determine the effects of a variable process of AgNps mediated mangrove Rhizophora stylosa (RS) leaf extract, and antibacterial activity.

8. Paving the way for using carbon nanocolloids in technological applications, 11 Dec, 2020, an international team of researchers, including researchers from FAU headed by Prof. Dr. Dirk M. Guldi from the Chair of Physical Chemistry have now managed to identify the fundamental problems relating to the photophysics and photochemistry of carbon nanocolloids (CNC), and ascertain possible approaches in the area of research into these readily available, non-toxic and adaptable nanomaterials.

NATIONAL STATUS OF RESEARCH

1. Subhranshu Sekhar Samal, S.R. Manohara, 2019, Nanoscience and Nanotechnology in India: A broad perspective, in this paper initiatives and outcomes in the area of nanoscience and nanotechnology will be projected which will be a ready reference for the young researchers, early career scientists, PhD students and aspirants for research. The outcomes of support from the government in the area of nanotechnology will be discussed and initiatives will be presented.

2. Krishan K. Verma, Abhishek Joshi, Vishnu D. Rajput, Jaya Arora, Munna Singh, Xiu-Peng Song, Dan-Dan Tian, Tatiana Minkina, Yang-Rui Li, 5 Jan, 2022, Recent Trends in Nano-Fertilizers for sustainable agriculture under climate change for global food security, accordingly, nanoparticles are emerging as a cutting-edge Agri-technology for Agri-improvement in the near future. Nano-Fertilizers do confer stress resistance capabilities to crop plants. To update researchers, the effective and appropriate mechanisms are revealed in this article.

3. Ashutosh Kumar Verma, P. Kumar, 29 June, 2022, On Recent developments in Biosynthesis and application of Au and Ag NPs from biological system, this review focuses on recent developments of green synthesized Au NPs and Ag NPs using biogenic sources such as algae, animals, plants, microbes, bacteria, fungi, and so on. It discusses separation of Au and Ag nanoparticles from plants, bacteria, fungi, and algae and their numerous biomedical applications.

4. Archana Singh, Harish Kumar Dubey, Smita Dubey, May, 2019, Nanotechnology: The Future Engineering, the future engineering is expected to be based on nanotechnology. From past researches it is revealed that it has potential applications in energy harvesting, energy production, temperature control, sensors and transducers with high conversion efficiency etc. The business forecast says is has a lots of scope in future business too. Although, the products manufactured on the technology of nanoscale are little costly but due to their better efficiency and reduced physical dimension it is well accepted in the market. The paper speaks about various Nanotechnology based applicative research carried out.

5. Shivani Kushwaha, Dr. Jaya Singh Bisen, Pragya Srivastava, “Combining studies on preparation of metal Nanoparticles from plant extract as Nano-Antibiotic”, IJSR, Dec., 2019, says about the plants contain antimicrobial activity can be employed for the nanoparticle creation. The nanoparticles can be used as tablets and also in suspension. The multi drug resistant pathogens would be hindered as its strain could be altered for our aim.

6. P. K. Bajpal, S. Yadav, A. Tiwari & H. S. Virk, 2015, “Recent Advances in the synthesis and characterization of chalcogenide Nanoparticles”, Nanoparticles and

self-assemblies of CdSe, CdTe, HgTe and ZnSe are synthesized using new and facile single molecular precursor based noble route that uses non-pyrophoric, Low temperature and non-toxic chemicals, their properties and synthesis scheme are discussed as future development in this field.

Proposed methodology and characterization

A survey of the scientific literature reveals that worldwide research activities on semiconductor nanoparticles or quantum dots are being perused with possible applications in electronics, space, optoelectronics, memories, biomedical field etc. Most of the reported work has utilized powder precipitation followed by chemical co-precipitation method. The rich crystal chemistry in wurtzite quantum dot systems offers excellent opportunities for understanding and fine-tuning the super bio electrical properties of nanoparticles by chemical manipulations.

Chemical co-precipitation method will be used for synthesize ii - iv group core shell nanoparticles using Alovera extract as capping agent at different molarities and temperatures. We will examine the influence of the growth process variables on the size and structure. Structural, morphological analysis and magnetic properties will be investigated using XRD, SEM, TEM, XPS etc. RAMAN will be used to confirm attachment of different functional groups in each step of fictionalization. A brief description of the characterization strategies to be adopted has been given in the following section:

1. Structural Analysis

X-Ray diffraction technique has been widely used for structural characterization. It depends upon Braggs diffraction law. This is reliable technique to find out the crystal

structure lattice parameter. Crystalline size can be obtained by Deby Scherrer formula. In general the broadening of the diffraction profile can be used to calculate the average particle size and non-uniform strain, while the peak shift can be used for the estimation of uniform micro strain.

2. Morphological Analysis

Morphological analysis will be carried out using AFM, SEM, RAMAN and TEM. SEM or AFM are the best surface topographic techniques with atomic scale resolution. For magnetic materials many kinds of magnetic interactions are measured by MFM, including magnetic dipole–dipole interaction.

Transmission electron microscopy (TEM) will be used in the determination of particle size. It gives access to a number-weighted mean value. High-resolution transmission electron microscopy (HR-TEM) gives access to the atomic arrangement. It will be used to study local microstructures (such as lattice vacancies and defects, lattice fringe, glide plane, or screw axes) and the surface atomic arrangement of crystalline nanoparticles.

3. Antimicrobial Activity

Bacterial activity is routinely used to assess biological properties. The antibacterial activities of ZnSe/CdSe Quantum Dots against Escherichia coli (E. coli) & Salmonella Pullorum (S. Pullorum) will be systematically investigated.

Work Plan

Year I (Jan 1, 2023-Dec 31, 2023)

Description of the work	Jan 2023	Feb 2023	Mar 2023	Apr 2023	May 2023	June 2023	July 2023	Aug 2023	Sep 2023	Oct 2023	Nov 2023	Dec 2023
Theory development and literature review												
Survey of Plant Extract												
Synthesis of Conventional core shell												
Characterization of Conventional core shell using HRTEM, XRD, etc. & submit two different papers												

Year II (Jan 1, 2024-Dec 31, 2024)

Description of the work	Jan 2024	Feb 2024	Mar 2024	Apr 2024	May 2024	June 2024	July 2024	Aug 2024	Sep 2024	Oct 2024	Nov 2024	Dec 2024
Characterization of Inverted core shell using HRTEM, XRD, SEM, PL,UV, RAMAN												
Structural Analysis Data interpretation												
Morphological Analysis Data interpretation												
Antimicrobial Activity and final Thesis preparation												

Expected Outcome

The proposed study is expected to lead to the following outcomes

1. An inexpensive facile route for growth of ZnSe/CdSe nanoparticles will be developed which is expected to be useful for biological imaging, sensing and detection.

2. Enhanced understanding of the physical properties of the QD nanoparticles and their interdependence will also emerge from the proposed studies.

3. The developed route can be expected to be suitable for the low cost synthesis of other core-shell nanoparticles.

4. The effective band gap due to switching between the exciton Type-I and Type-II.

5. The work will be presented in conferences and published in peer reviewed journals.

6. ZnSe/CdSe nanocrystals using plant extract has potential for process patents.

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2. Donald D. Hile, Hendrik C-Swart, Setumo V. Motloung, Lehlononolo F. Koao (2022) “ZeSe Semiconductor: Synthesis, properties and applications”
3. Advances in CMP polishing Technologies (2012)
4. www.en.m.wikipedia.org
5. Justin Tom (2021) “UV-Vis Spectroscopy: Principle, Strengths and Limitations and Applications”
6. Xin Tong, Zhiming M. Wang (2020) “Core/Shell Quantum Dots, Synthesis, Preperties and Devices”
7. Shweta Yadav (2018) “Synthesis of Selective Noble NPs with reference to geometries and their possible influence on efficacies against mosquitoes of Public Health significance”
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14. Hangbo Li, Rosaria Brescia, Roman Krahne, Giovanni Bertoni Marcelo J.P. Alcocer, Cosimo D’Andrea Francesco scotognella, Francesco Tassone, Macro zanella, Milena De Giorgi and Liberato Manna (2012) “Blue-UV-Emitting ZeSe (Dots/ZnS) Core/Shell Nanocrystals by Sequential cation exchange”
15. Kumar P. Singh, K. Wurtzite (2009) “ZnSe Quantum dots: synthesis, characterization and PL properties J. opt electron Biomed Mater”

16. Song, K.K., Lee, S. Highly (2001) “Luminescent (ZnSe) ZnSe Core/Shell Quantum Dots for Blue to UV Emission: Synthesis and characterization. Curr. Appl. Phys.”

17. Goswami, B.; Pal, S.; Sarkar, P. (2008) “A Theoretical study on the Electronic Structure of ZnSe/ZnS and ZnS/ZnSe Core/Shell Nanoparticles. J. Phys. Chem. C.”

18. Zhu, D.; Jiang, X.; Zhao, C.; Sun, X.; Zhang, J.; Zhu, J.-J. (2010) “Green Synthesis and potential Application of Low-Toxic Mn: ZnSe/ZnS Core/Shell Luminescent Nanocrystals. Chem. Commun."

19. Jianping Ge, Sheng Xu, Jing Zhuang, Xunwang (2006) “Synthesis of CdSe, ZnSe and Zn x Cd1-x Se Nanocrystals and their Silica Sheathed core/shell structures”.

20. Assaf Aharoni, Taleb Mokari, Inna Popov and Uri Banin (2005) “Synthesis of InAs/CdSe/ZnSe/core/shell1/shell2 Structures with Bright and Stable Near-Infrared Fluorescence”.

21. F. Farsinia, M. Moalei, M. Dehestani and H. Alehdaghi (2019) “White emmisive alloyed core-shell $CdSe_{1-x}S_x$/ZnSe QDs: Synthesis via a novel approach, investigating optical properties and application for photodegradation of methyl orange (MO)”.

22. Irshad Ahmad Mir, Kamla Rawat, H.B. Bohidar(2016) “Cadmium-free aqueous synthesis of ZnSe and ZnSe@ZnS core-shell quantum dots and their differential bioanalytic sensing potential”.

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24. Hakan Aydin, M.R. Karim, Mesut Balban, Hilmi Unlu (2016) “Colloidal Synthesis and Characterization of Cd:Se Molar Ratio and Temperature”

25. Nancy Willian, Syukri Syukri, Hilfi Pardi (16 May, 2022) “Marine plant mediated green synthesis of silver nanoparticles using mangrove Rhizophora stylosa: Effect of variable process and their antibacterial activity”

26. Gabriel Amani Kaningini, Shohreh Azizi, Keletso Cecilia Mohale, Malik Maaza (23 Aug, 2022) “Green synthesis and characterization of zinc oxide nanoparticles using bush tea (Athrixia phylicoides DC) natural extract: assessment of the synthesis process”

27. “Bichiral nanoparticles: A new Structural design for manipulating the spin state of light” (18 Oct, 2022) (www.nanowerk.com)

28. Liu S, Li J, Gu L, Wu K, Xing H (7 Nov, 2022) "Nanoparticles for Chemoimmunotherapy against Triple-Negative Breast Cancer"

29. Prof. Dr. Dirk M. Guldi (11 Dec, 2020) "Paving the way for using carbon nanocolloids in technological applications" (www.fau.eu)

30. "Researchers analyzed circulating currents inside gold nanoparticles university of Jyvaskyla, Finland" (30 April, 2021), News from (www.science.com)

31. "Magnetic nanoparticles in biological vehicles individually characterized for the first time, Helmholtz-zentrum Berlin fur Materialien und Energie" (17 May,2022), News from (www.science.com)

32. "Heat-efficient nanoparticles for treating cancer, Oregon State University" (15 Nov, 2022), News from (www.science.com)

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